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A BRIEF COMPARISON OF RING AND ASYMMETRICAL BAFFLE CHARACTERISTICS

by

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LIST OF SYMBOLS

a	Longitudinal acceleration of tank
d	Cylindrical tank diameter
d_s	Distance from top of baffle to liquid surface
h	Liquid depth to bottom of tank
R	Cylindrical tank radius
W	Baffle width
X_o	Tank excitation amplitude in translation
ω_n	Liquid natural circular frequency
$\omega^2 d/a$	Dimensionless frequency parameter
γ_s	Damping ratio

INTRODUCTION

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Because of the need to provide an adequate degree of damping of fuel sloshing in missile tanks, a constant search is being conducted for improved baffling systems. Upon completion of an extensive study of ring baffle damping and liquid resonance effects (1), it was decided to compare these results with experimental studies of equal area asymmetrical baffles similar to those described in (2). The experimental comparison is made for a number of directions of translation excitation and for various baffle depths below the liquid surface.

The experimental procedure and test equipment are similar to those employed in (3).

LIQUID RESONANT FREQUENCIES

The liquid resonant frequencies in cylindrical tanks containing ring baffles are strongly dependent upon the location of the baffles below the liquid surface, but are independent of the direction of excitation. For cylindrical tanks containing asymmetrical baffles of the type described in (2), however, the direction of tank excitation plays a predominant part in determining the lowest liquid resonant frequencies.

The accompanying figure shows the experimental liquid resonant frequencies in terms of two dimensionless parameters (the frequency $\omega^2 d/a$ and the baffle depth d_s/R) for the various test configurations. Included in the figure for comparative purposes is the lowest resonant frequency for an undamped liquid in a cylindrical tank (which is a constant for small amplitudes and for $h/d > 1$). It may be noted that for all baffle configurations where $|d_s/R| \leq 0.05$, the liquid resonant frequency is increased over that for an unbaffled tank. For depths greater than $d_s/R = 0.05$, the liquid resonant frequency of a ring-baffled tank decreases to a minimum value which is less than the undamped natural frequency, near a depth of $d_s/R = 0.1$, and then gradually increases with depth, eventually approaching the undamped natural frequency.

For asymmetrical baffles the liquid resonant frequencies remain above the undamped value to a baffle depth of about $d_s/R = 0.1$;

however, at a depth of $d_s/R = 0.12$, the liquid resonant frequency for certain directions of tank excitation drops below that for a ring-baffled tank. As in the case of a ring-baffled tank, these liquid resonant frequencies gradually increase with baffle depth toward the undamped natural frequency. It may be noted that for asymmetrical-baffled tanks a number of resonant frequencies can be excited for baffled tanks between $d_s/R = 0.12$ and $d_s/R = 0.25$, as represented in the accompanying figure by open and solid data points.

Because of the wide range in resonant frequencies that can be excited, depending on the direction of excitation, it appears impossible to predict the most significant liquid resonant frequencies for an asymmetrical baffled tank. However, additional tests with a series of asymmetrical baffles at various depths may prove these baffles to be an efficient damping system.

LIQUID DAMPING

Liquid damping in asymmetrical-baffled, cylindrical tanks is dependent on the baffle depth below the liquid surface and the direction of tank excitation relative to the baffle locations. It is well known that the amplitude of excitation also affects damping, but for this comparison only one excitation amplitude, $X_o/d = .00417$, is considered. Because the direction of excitation in a missile is arbitrary, the lowest damping values produced by asymmetrical baffles are considered critical for comparative purposes.

Shown in the accompanying figure are the experimental liquid damping ratios corresponding to various baffle depths for ring-baffled and asymmetrical-baffled tanks undergoing translation excitation for each of three baffle orientations. It may be seen from this comparison that the damping ratio is considerably higher for ring baffles than for asymmetrical baffles at depths from $d_s/R \cong 0$ to $d_s/R \cong 0.12$. At greater baffle depths the damping factors produced by both the ring and the asymmetrical baffles are very similar and agree with damping ratios calculated from Miles' equation (4) using liquid sloshing heights measured from ring-baffled tanks. Also, it may be noted that for asymmetrical baffle depths from $d_s/R = 0.12$ to $d_s/R = 0.25$, certain baffle orientations with respect to the direction of excitation produce more damping than is obtainable from a ring baffle. This, however, represents a qualification which can hardly be accounted for in the design processes required in actual vehicle applications.

CONCLUSIONS

The results presented in this paper indicate that a ring baffle is far more effective than an asymmetrical baffle at baffle depths from $d_s/R = 0$ to $d_s/R = 0.12$, and that the effectiveness of both types of baffles is about equal at greater depths. The present results are in contrast with those presented in (2), where the asymmetrical baffle appears to be the more effective. The source of the discrepancy may be in the baffle areas considered. For the present results, a baffle area equivalent to 28.6% of the tank diametrical area is considered, whereas a baffle area of approximately 16% is considered in (2). It may be pointed out that the effectiveness of ring baffles increases considerably with ring width at depths of less than $d_s/R = 0.12$. This effect is presented in (5).

Because the frequency response and damping ratios for the asymmetrical baffle vary with direction of tank translation excitation, it appears that such a system should not be considered for actual use without an extensive test program. Such a test program would prove very costly for it would require tests of various type baffles, baffle staggering, baffle depth locations, numerous directions of translation excitation, and probably a number of translation excitation amplitudes. The volume of data thereby obtained almost in itself precludes its employment in design.

Finally, it appears that a much heavier construction would be required for an asymmetrical baffle than for a ring baffle having equal area, because of the greater span exposed to the sloshing liquid.

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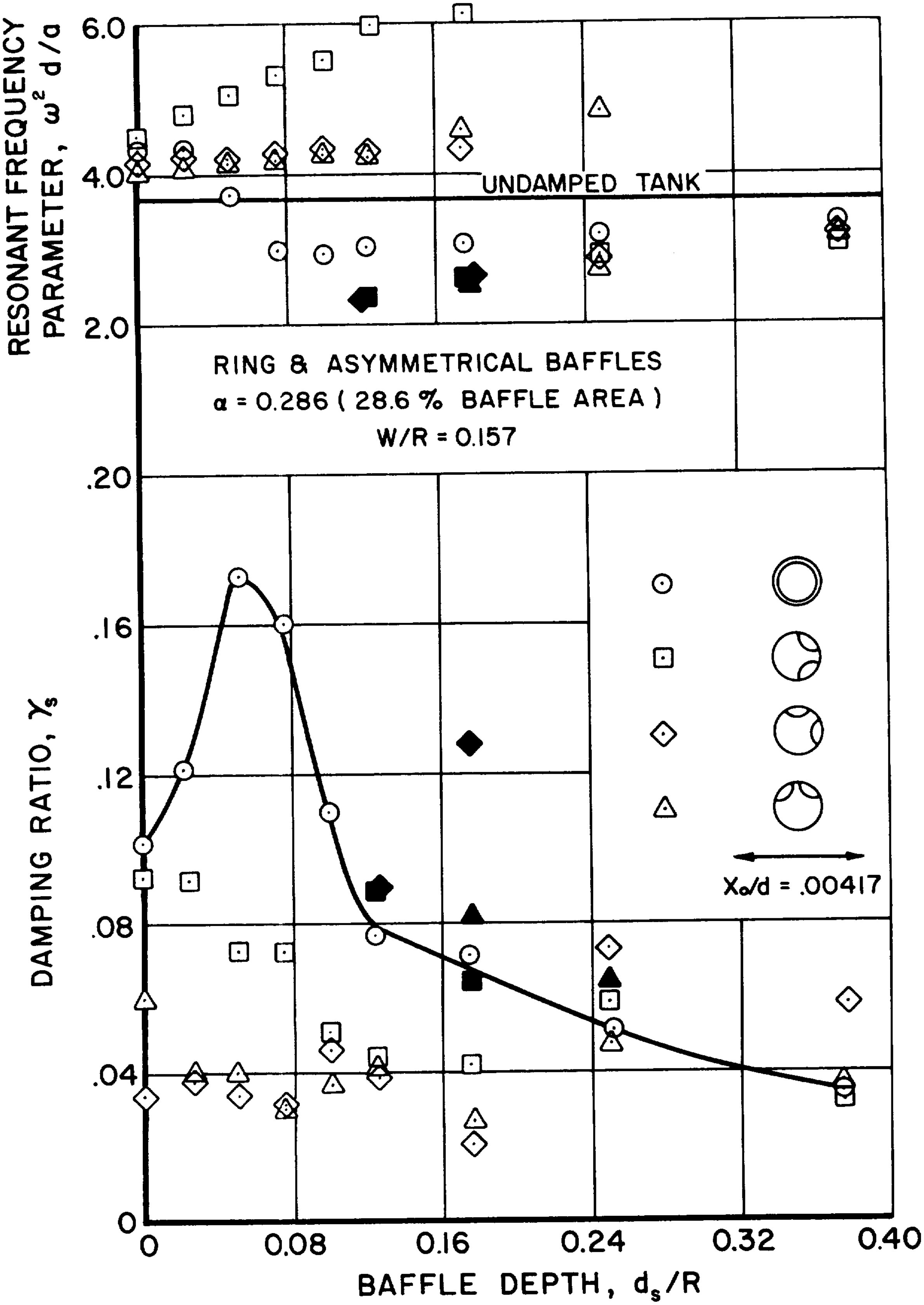

LIQUID RESONANT FREQUENCIES AND DAMPING RATIOS FOR RING AND ASYMMETRICAL BAFFLED TANKS